a relatively quiescent period of solar activity and could be developed normally. It exhibits essentially the same frequency of terminating $Z \geqslant 6$ particles as the balloons launched at 55°N, and the tracks enter isotropically. A comparison of the two satellite exposures indicates that during the 3+ flare the flux of $Z \geqslant 6$ particles capable of terminating in the detectors increased about 100-fold. The greater part of the 900 ± 300 cc^{-1} day^{-1} termination frequency is due to the $Z = 6 \pm 2$ group. If we assume that our low-magnification estimate[5] of 13 ± 3 cc^{-1} day^{-1} applies to the more conspicuous tracks of $Z \geqslant 10$, then the M/H ratio during a flare is ~70 as compared with a value of 3 for the galactic heavy primaries. The large uncertainty in the $Z \geqslant 6$ population is not statistical in character, but originates from the sampling position, which reaches a maximum in the first emulsion sheet facing the thin window. The over-all evidence indicates that a beam of particles of $Z = 6 \pm 2$ was emitted from the sun during the 3+ flare.

This identification is consistent with the observation by Fichtel and Guss[6] of a flux of carbon, nitrogen, and oxygen nuclei associated with a flare of magnitude 3, detected by nuclear emulsions flown to 130 km at 1480 U.T. on September 3, 1960. On the other hand, Kurnosova and co-workers[7] report an anomalously large flux of nuclei with $Z \geqslant 15$ associated with a Class 1^{-} flare which occurred at 1127 U.T. on September 12, 1959. Their observations are based on two Čerenkov counters carried on the second U.S.S.R. cosmic rocket which responded to heavy particles with energies exceeding 1.5 Bev/nucleon. During the 17-minute period when the flux of $Z \geqslant 15$ increased about twelvefold, the fluxes of particles with $Z \geqslant 2$ and $Z \geqslant 5$ remained essentially normal.

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EVIDENCE FOR A π-π RESONANCE IN THE $I=1$, $J=1$ STATE*

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(Received May 11, 1961)

Since the earliest data became available on pion production by pions, certain features have been quite clear. The main feature which is strongly exhibited above energies of 1 Bev is that collisions are preferred in which there is a small momentum transfer to the nucleon.[1] This is shown by the nucleon angular distributions which are sharply peaked in the backward direction. These results suggest that large-impact-parameter collisions are important in such processes. The simplest process that could give rise to such collisions is a pion-pion collision with the target pion furnished in a virtual state by the nucleon. The quantitative aspects of such collisions have been discussed by a number of authors. Goebel, Chew and Low, and Salzman and Salzman[2] discussed means of extracting from the data the π-π cross section. Holladay and Frazer and Fulco[3] deduced from electromagnetic data that indeed there must be a strong pion-pion interaction. In particular, Frazer and Fulco deduced that there probably was a resonance in the $I=1$, $J=1$ state. A qualitative set of π-p phase shifts in the 400-600 Mev[4] region were used by Bowcock et al.[5] to deduce an energy of about 660 Mev in the π-π system for the resonance. The work of Pickup et al.[6] showed an indication of a peak in the π-π spectrum at an energy of about 600 Mev.

The present experiment was designed to explore the π-π system up to an energy of about 1 Bev. The π^- beam was produced by the external proton beam No. 1 at the Cosmotron. A suitable set of quadrupole and bending magnets focussed the pion beam on a Hevimet slit about 10 ft from the Adair-

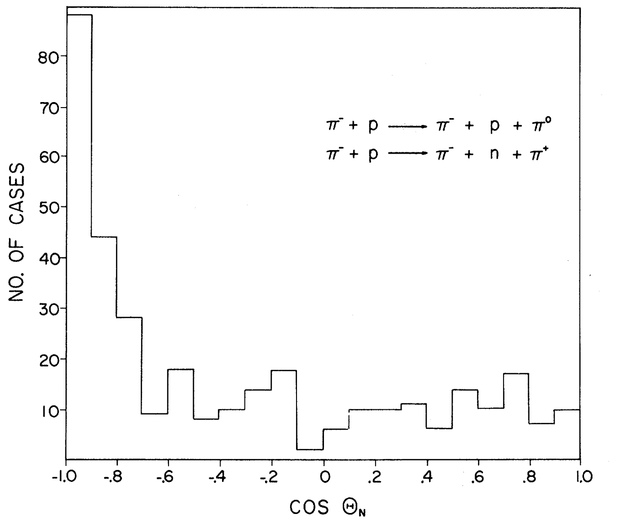

FIG. 1. The angular distribution of the nucleons from the processes $\pi^- + p \rightarrow \pi^- + \pi^0 + p$ and $\pi^- + p \rightarrow \pi^- + \pi^+ + n$.

Leipuner 14-in. H_2 bubble chamber. The pions were guided into the chamber by another bending magnet. The measured momentum was 1.89 ± 0.07 Bev/c.

Events selected for measurement were taken in a fiducial volume of the chamber. The forward-going track was required to be at least 10 cm long. Measurements were made on a digitized system and the output was analyzed by use of an IBM-704. The events were analyzed by means of a program based on the "Guts" routine written by members of the Alvarez bubble chamber group.

Figure 1 shows the combined angular distribution for the nucleons from the two processes, $\pi^- + p \rightarrow \pi^- + \pi^0 + p$ and $\pi^- + p \rightarrow \pi^- + \pi^+ + n$, which appear to be identical within statistics. The results indicate a large number of events with small momentum transfer to the nucleons.

We concentrate our interest on those events with small momentum transfer since these events satisfy the qualitative criterion of being examples of π-π collisions. Somewhat arbitrarily, we center our attention on cases in which the momentum transfer to the nucleon is less than 400 Mev/c. Table I gives the ratios of the three possible final states $\pi^-\pi^+n$, $\pi^-\pi^0p$, and $\pi^0\pi^0n$, assuming the π-π scattering to be dominated, respectively, by the $I = 0$, 1, 2 scattering states of the π-π system.

The experimental results in the last column indicate a strong domination by $I = 1$ state. For the $I = 1$ state the basic π-π scattering cross sections $\sigma(\pi^-\pi^0 \rightarrow \pi^-\pi^0)$ and $\sigma(\pi^-\pi^+ \rightarrow \pi^-\pi^+)$ are equal.

Table I. Ratios of final states.

	$I = 0$	$I = 1$	$I = 2$	Experiment ($\Delta \leqslant 400$ Mev/c)
$\pi^-\pi^+n$	2	2	2/9	1.7 ± 0.3
$\pi^-\pi^0p$	0	1	1	1
$\pi^0\pi^0n$	1	0	4/9	$< 0.25 \pm 0.25$

The nucleon four-momentum transfer spectrum seems to be in qualitative agreement with the theory for the process in which a π is knocked out of the cloud. Figure 2 shows ideograms for the mass spectrum of the di-pions for cases with $\Delta \leqslant 400$ Mev/c and $\Delta > 400$ Mev/c, where Δ is the four-momentum transfer to the nucleon. The curve for $\Delta \leqslant 400$ Mev/c clearly shows a peak at 765 Mev/c. In the ideogram for $\Delta > 400$ Mev/c the peak is still present but seems to be smeared to higher values of the di-pion mass, m^*. One worries that diagrams other than the one involving

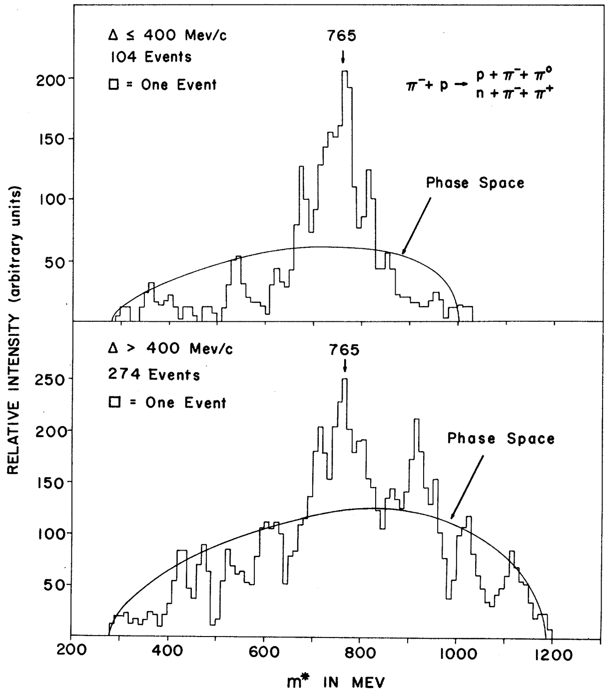

FIG. 2. The combined mass spectrum for the $\pi^-\pi^0$ and $\pi^-\pi^+$ system. The smooth curve is phase space as modified for the included momentum transfer and normalized to the number of events plotted. Events used in the upper distribution are not contained in the lower distribution.

one-pion exchange might be contributing to the observed peak in this m^* spectrum. In particular, an important contribution at lower energies comes from a diagram in which one of the π's rescatters off the nucleon and ends up in the 3-3 state with respect to the nucleon. If one restricts the data to cases with $\Delta \leq 400$ Mev/c this diagram does not seem to be very important, but if one takes cases with $\Delta > 400$ Mev/c many cases consistent with rescattering are found.

In order to deduce values of the π-π cross section, we use the formula[2]

$$\frac{d^2\sigma}{dm^*d\Delta^2} = \frac{3f^2}{\pi}\frac{\Delta^2}{(\Delta^2+1)^2}\left(\frac{m^*}{q_{iL}}\right)^2 K\bar{\sigma}_{\pi\text{-}\pi},$$

where $\bar{\sigma}_{\pi\text{-}\pi}$ is the mean of $\sigma(\pi^-\pi^0 \rightarrow \pi^-\pi^0)$ and $\sigma(\pi^-\pi^+ \rightarrow \pi^-\pi^+)$. In the above formula all momenta and energies are measured in units of pion masses. q_{iL} = momentum of the incoming pion measured in units of the pion mass. K = momentum of the pions in the di-pion center-of-mass system. Then

$$\delta\sigma = \frac{3f^2}{\pi}\left(\frac{m^*}{q_{iL}}\right)^2 K\bar{\sigma}_{\pi\text{-}\pi}\,\delta m^* \int_{\Delta_{\min}(m^*)}^{\Delta_{\max}} \frac{\Delta^2 d\Delta^2}{(\Delta^2+1)^2}.$$

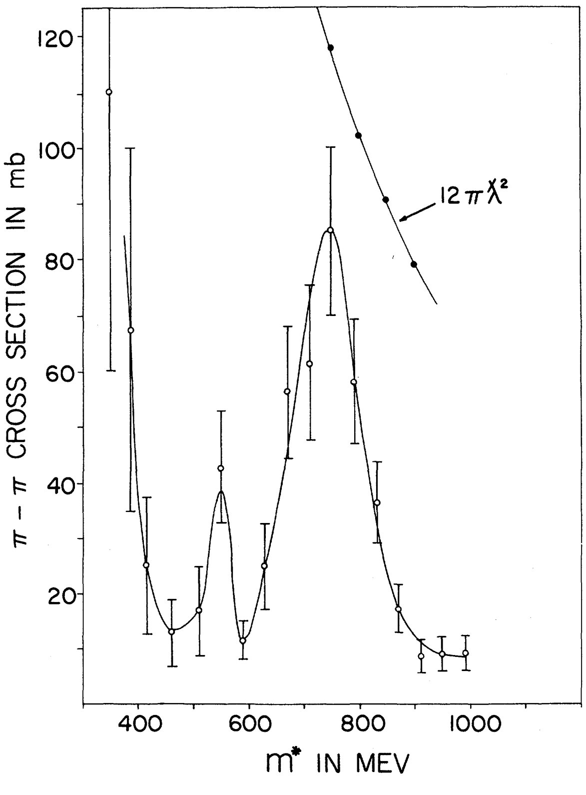

FIG. 3. The π-π cross section as deduced from cases with the four-momentum transfer less than 400 Mev/c.

The results of this calculation using the experimentally determined $\delta\sigma$'s are shown in Fig. 3. The results indicate a peak in the neighborhood of 750 Mev with a width of 150-200 Mev, which is about 3/4 of what it would be ($12\pi\lambda\!\!\!^-{}^2$) for a resonance in the $I=1$, $J=1$ state. Since this cross section was determined off the energy shell, it is difficult to estimate the effect of the interference of other diagrams and also the effect of line broadening.[7] Whether or not the other peak and the S-wave scattering indicated in Fig. 3 are real will have to await better statistics for verification.

We wish to acknowledge with gratitude the help and cooperation of R. K. Adair and L. Leipuner in the use of their bubble chamber, and to the latter also for his assistance in adapting the "Guts" routine to our use. We also acknowledge the help of J. Boyd, J. Bishop, P. Satterblom, R. P. Chen, C. Seaver, and K. Eggman in measuring, scanning, and tabulating. We were greatly aided by Dr. J. Ballam and Dr. H. Fechter in setting up the beam. We have had helpful conversations with Dr. R. K. Adair, Dr. C. J. Goebel, Dr. M. L. Good, and in particular Dr. G. Takeda.

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*Work supported in part by the U. S. Atomic Energy Commission and Wisconsin Alumni Research Foundation.

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